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THE PARAFFINED WIRE BASKET METHOD OF SOIL INVESTIGATION OF THE BUREAU OF SOILS, UNITED STATES DEPARTMENT OF AGRICU TURE.

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The following paragraphs are quoted from Circular 22 of the Office of the Secretary, United States Department of Agriculture, the author of this circular being Prof. W. M. Hays, Assistant Secretary of Agriculture.

THE SECRETARY OF AGRICULTURE:

Sir:—By your reference I have investigated certain charges against the Bureau of Soils and Prof. Whitney, Chief thereof, made in letters of, and in an address by, Dr. Cyril G. Hopkins, President of the Association of Official Agricultural Chemists, and Professor of Agricultural Chemistry and Agronomy in the University of Illinois.

My investigation has been directed to the charges against the honesty and good faith of Professor Whitney and the Bureau of Soils, without regard to the scientific points at issue between that Bureau and Doctor Hopkins.

In an open letter dated March 26, 1906, addressed to Prof. Chas. E. Thorne, Director of the Ohio Experiment Station, copies of which were sent to the Secretary of Agriculture, Members of Congress, and various station directors throughout the country, Dr. Hopkins charged—

(1) That the field results of the Ohio station, as stated in Bulletin 167 of that station, do not agree with the results obtained by the pot-culture and water-culture methods of the Bureau of Soils.

(2) That in order to show an apparent agreement between the results of the field experiments of the Ohio station and the results obtained by methods of the Bureau of Soils, material data regarding nitrogen cultures had been suppressed by that Bureau.

(3) Inferentially, Dr. Hopkins charged that the Ohio station authorities were not responsible and did not stand for the results set out in Bulletin 167 of that station, and permitted the conclusions to be included in the said bulletin without their indorsement.

After a careful investigation and a thorough examination of the records and correspondence pertaining thereto, I have found that none of the above charges are justified or warranted.

The publication of this circular, together with the fact that some leading soil investigators have been in doubt as to the attitude

of this station towards the work under criticism, seem to make it necessary to distinctly define that attitude.

In December, 1904, I attended an informal conference, held at the Bureau of Soils, United States Department of Agriculture on invitation of the Chief of that Bureau, Dr. Milton Whitney, the object of which was to discuss certain methods of soil investigation. At this conference Dr. Whitney exhibited some very interesting results obtained by the use of a paraffined wire basket method of soil investigation, recently devised or improved in his Bureau, and expressed a desire to undertake cooperative studies with this method at some of the experiment stations. As the Ohio station had been conducting field experiments with various fertilizing materials for a number of years, it seemed that the plots on which these experiments were located, and which were then showing very marked differences in productiveness, due to their previous treatment, would offer an excellent opportunity to test this method, and Dr. Whitney was therefore invited to send a party to the Ohio Experiment Station to conduct a line of investigations by this method.

Pursuant to this invitation a party from the Bureau of Soils took up this work at the Ohio Station February 1, 1905, and continued it for several months; the work at the outset being planned and directed, and its results prepared for publication, by the Bureau of Soils.

It was agreed that these results should be published in a bulletin of the Ohio Experiment Station, and they were so published in No. 167 of that series.

Later on another series of investigations was undertaken by the same party on the soil of the Northeastern Test-farm at Strongsville. The direction of this work was left with myself, and it was directed chiefly to a study of the physical condition and lime requirement of the soil of that farm. Its results were published in Bulletin 168 of this station.

In the introduction to Bulletin 167 the object of the work was outlined by the Bureau of Soils in the following paragraphs:—

For many years plot experiments on the problems of productiveness in agricultural soils have been in progress at Wooster, Ohio, on the farm of the Ohio Agricultural Experiment Station. These experiments, carried on under the direct supervision of Prof Chas. E. Thorne, have been so carefully planned and have extended over so long a series of years that the recorded results are very valuable for comparative studies.

The Bureau of Soils, desiring to determine whether the results obtained by its wire-basket and aqueous-extract methods of studying the productiveness and manurial requirements of soils were in accord with those secured through plot experiments found in the records of the Wooster experiments a valuable means to this end.

I. COMPARISON OF FIELD RESULTS WITH THOSE OBTAINED BY THE BUREAU OF SOILS.

The field experiments, with which it was proposed to compare the wire basket method, were begun in 1893, in a 5-year rotation of corn, oats, wheat, clover and timothy, Five tracts of land were employed, in order that each crop might be represented every season. The work was begun by planting corn on one tract in the spring of 1893 and sowing wheat on another in the fall of that year.

It was deemed advisable to select for the preliminary basket work soil as nearly as possible of the same character as the original soil upon which the field work was located, but which had not been subjected to treatment with fertilizers; accordingly a sample of soil was taken, with my approval, not from the area actually under experiment, but from land of the same general character. I have seen no reason to believe that this point has materially affected the outcome of the test; but a duplicate test, on a small scale, was made on extracts of soils taken from two of the experiment plots. (Bulletin 167, page 112)

In the wire basket test on the soil first mentioned the addition of phosphorus seemed to have a depressing effect on the yield, and the Bureau of Soils called attention to the fact that similar depressions had followed the use of this substance in two notable cases in the station's field experiments. Attention was also called to the cumulative effect of the fertilizers in the station's field tests, and it was stated that for this reason the later results obtained in these field experiments should not be compared with those obtained in the basket and bottle cultures (Bulletin 167, page 108) and yet just this comparison was attempted, with bottle cultures, on page 115 of the same bulletin, and on page 116 the following conclusions were reached;

"It appears from these considerations that, while, as in case of all work of this kind, there are a few discrepancies, the general conclusions from the field experiments, both at the beginning in 1894 and in their more advanced stages, are in agreement with those from the experiments carried on by the methods of basket cultures and cultures in soil extract."

This conclusion is repeated by the Chief of the Bureau of Soils in his preface to Bulletin 168 (page 122) as follows:

"The results of the two investigations at Wooster and Strongsville leave no reasonable doubt that the paraffin pot method does give results in harmony with the average results obtained by the much longer timed experiments in the field. It thus has an unquestionable value as a practical method for investigating the manurial requirements of a soil. But it has also been shown to be a valuable instrument of research which will probaby enable plot experimenters in the future to save many years of labor, although in no way can it be regarded as supplanting or depreciating the more certain results which long time plot experiments alone can furnish."

The statements in this and other publications of the Bureau of Soils have given opportunity for uncertainty as to what was actually in the minds of the authors, and in an address, delivered as President of the Association of Official Agricultural Chemists, afterwards published as Circular 105 of the Agricultural Experiment Station of the University of Illinois, Dr. Cyril G. Hopkins justly criticises the above conclusions as not being justified by the facts published.

The table on page 110 of Bulletin 167 brings out very conspicuously the uncertainty attending the first application of fertilizing chemicals. In not one of the four corn crops included in that table was the order of effectiveness of the different fertilizer combinations, as measured by the total weight of increase, in harmony with the average of the four crops, nor with the 7- to 9-year average results as tabulated on page 71 of Bulletin 141 of this station.

This last named table, however, shows that, in the longer average, the relative effectiveness of the various combinations on the different crops has been remarkably uniform, as shown below:

ORDER OF EFFECTIVENESS OF FERTILIZER COMBINATIONS IN 5-YEAR ROTATION.

Combinations.	9-Year average.			7-Year Average		Total
	Corn	Oats	Wheat	Clover	Timothy	
Potassium	2	1	1	1	3	1
Nitrogen	1	2	2	2	5	2
Nitrogen, potassium	3	3	3	3	2	3
Phosphorus	4	4	4	4	1	4
Phosphorus, potassium	5	5	5	5	4	5
Phosphorus, nitrogen	6	6	6	6	6	6
Phosphorus, nitrogen, potassium	7	7	7	7	7	7

The timothy, coming two years after a fertilized crop, shows a less regular order of effectiveness than the other crops, but even this crop follows the same order for the combinations of phosphorus with nitrogen. In the other four crops the transposition of the nitrogen and potassium for the corn crop is the only departure from the regular order.

If we were to take the 13-year average, which is now available, the relative order would remain unchanged for the cereal crops, but for the clover and timothy the combinations containing nitrate of soda would become comparatively more important, probably because of the influence of the sodium in neutralizing the increasing acidity of the soil on which this experiment is located.

I am inclined to ascribe the uncertain action of acid phosphate, when used alone in these tests, both in field and basket cultures, to slow availability or to possible absorption of the first application and its conversion into unavailable combinations. The very small

quantity used in the station's field experiments—80 pounds per acre on corn and oats, or 160 pounds on wheat—has often given negative results in the first crop, even when it has had several months in which to act. Certainly, then, we may expect uncertain results when it has only a few weeks for its action.

When applied in connection with manure, acid phosphate has produced a very great additional effect in the station's long continued tests; but even here the first application gave contradictory results.

After the first application, however, the plots receiving acid phosphate show a very marked acceleration of growth at a very early stage in the life of each crop.

In the station's field experiments plots No. 1, unfertilized, No. 2, receiving acid phosphate alone, No. 3, receiving muriate of potash alone, No. 4 unfertilized and No. 5, receiving nitrate of soda alone, stand side by side. Year after year, and on every cereal crop, since the first rotation, the growth on No. 2 has been conspicuously greater by the time the plants were two or three weeks old, and this lead has been maintained until harvest; whereas it has usually been impossible to distinguish any difference between the growth on Plots 3, 4 and 5, even up to the date of harvest, although in the average outcome Plots 3 and 5 have shown a small increase in yield. The same has been true of Plot 9, receiving the combination of the applications to Plots 2 and 3, as compared with the unfertilized plot, No. 10 alongside.

In the basket and soil extract cultures, however, nitrate of soda, whether used alone or in combination with muriate of potash, has regularly produced a much greater relative increase than in the field tests.

It is to be remembered that the same soil was under investigation, both in the field and in the pot cultures. If identical treatment gave opposite results by the two methods the necessity for further study of the method was indicated.

II. SUPPRESSION OF THE NITROGEN DATA.

Dr. Whitney states, in Circular 22, that it did not seem advisable to me to make any test with nitrates on the soil used for the basket cultures reported in Table I of Bulletin 167, thus implying that no such tests were made in that series, although it is stated on page 94 of Bulletin 167 that:—

> The first series of baskets was planned to determine the effect of the three most important fertilizer constituents: nitrogen, potash and phosphorus, and of lime and stable manure. All these substances were used alone and in combination with one another. * * * The results of this series are given in Table I.

These statements leave us in doubt as to whether separate tests were made with nitrate of soda and muriate of potash; but as to my position in the matter I would say that the very meager effect produced in this station's field experiments by the use of nitrogen or potassium, except when combined with phosphorus, had led me to doubt the usefulness of separate applications of either of these elements on ordinary soils, either in field or laboratory, and because of this doubt such applications have been omitted from field experiments planned and put into operation during recent years.

This fact, however, that the full effect of a fertilizing element may only be realized when it is combined with one or more other elements, makes some such method of computation as that which Dr. Hopkins has employed essential to a correct understanding of the real outcome of the test. As Dr. Whitney says, in his Circular 22:

" x x It is conceded by all authorities that the effects of a fertilizer are not usually additive, but that the influence of one fertilizer almost invariably modifies the effect which a second fertilizer would have, had it been added alone.'

This is precisely the point aimed at in Dr. Hopkins' method of calculation. He has not attempted to compute average values for the different elements by his calculation, but shows that the effect of any element will depend upon the combination in which it is used.

III. RESPONSIBILITY FOR CONCLUSIONS.

As has already been stated, Bulletin 167 of the Ohio Experiment Station was prepared by the Bureau of Soils, but was published by the station. In my preface to this bulletin I did not in set terms disclaim responsibility for the conclusions arrived at in the bulletin, assuming that its acknowledged authorship was sufficient on that score. In this preface, however, I said:

"The outcome of this work has been that the results obtained in two or three weeks' time are in general agreement with field tests which require an entire season for their execution.

Unfortunately, as it now appears, I separated this sentence from the concluding one of the preface, which was intended to convey my final conclusions, namely:

"*This much is sure, that no single season's field work on a particular soil is a sufficient basis on which to formulate a definite prescription for the fertilization of that soil, and it is highly probable that we shall find the same law holding good in the conduct of the method of investigation described in the following pages.*"

To put the matter in more definite form, I now offer the following as my opinion:

1. There are certain soil problems of great importance which can be studied better by pot cultures than in the field. Two such have been brought forward in the experiments above described, namely: the slow effect of first applications of acid phosphate, and the abnormal effect produced by nitrate of soda on pot culture seedlings, as compared with the results obtained in the field. For the study of such problems the paraffined wire basket possesses certain advantages over the small earthen or metal pot. But the small pot can never take the place of the large pot in studies which require that the plant should be carried to maturity, and as to substituting the wire basket for systematic field experiments I can not do better than to quote again from Dr. Whitney's preface to Bulletin 168 of this station:

"*In no way can it be regarded as supplanting or depreciating the more certain results which long time experiments alone can furnish.*"

2. The transpiration method of study applied to this basket by the Bureau of Soils is yet on trial. I expect it to be found more useful in physiological investigations than in the direct study of soil fertility.

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